

UNIVERSITY OF SASKATCHEWAN
DEPARTMENT OF CHEMISTRY
CHEMISTRY 111.3
FINAL EXAMINATION

April, 1997

NAME: _____
please print legibly!

Time: 3 hours

SIGNATURE: _____

STUDENT NO.: _____

Please indicate your Section:

02 Reid MWF 9:30 _____ C10 Walker (Melfort) _____
04 Baranski T Th 10:00 _____

INSTRUCTIONS:

1. This examination consists of 16 pages including a data sheet. Please ensure your paper is complete.
2. Answer all questions on the examination paper. For multiple choice questions, circle the correct answer on the examination paper and enter the answer on the blue optical scan sheet by filling in the appropriate circle with a dark pencil.
3. Complete the information required (name etc.) at the top of the optical scan sheet. Your Student Number is to be coded onto the upper left portion of the sheet reading downward. Note that the numbers in the code spots read from zero through nine as you read from left to right ... i.e. the first spot is 0, not 1.
4. Show your work in problem solutions. Ensure that your answer has the appropriate units and number of significant figures.
5. This is a closed book examination. The marks for each question are indicated. Total marks are 160. Allowing for reading the questions and checking over, this is 1 mark per minute; apportion your time accordingly.

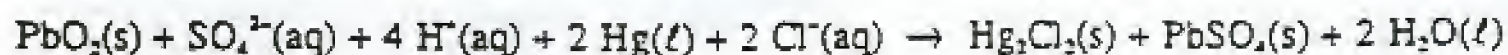
Additional Information:

$$K_w = 1.00 \times 10^{-14} \text{ at } 25^\circ\text{C} \quad \Delta E = E^\circ - \frac{0.0592}{n} \log_{10} Q \text{ at } 25^\circ\text{C} \quad (\text{Nernst Equation})$$

Question	Maximum Marks	Marks Awarded
1-25	50	
26-31	30	
32	20	
33	5	
34	5	
35	10	
36	10	
37	10	
38	15	
39	5	
Total	160	

I. Multiple Choice (2 marks each)

1. Identify the substance reduced in the reaction.



- A. PbO_2
 - B. SO_4^{2-}
 - C. Hg
 - D. H^+
 - E. none of these
2. If an acid has $K_a = 4.93 \times 10^{-10}$, then K_b for its conjugate base is
- A. 9.95×10^{-3}
 - B. 5.17×10^{-4}
 - C. 5.17×10^{-10}
 - D. 2.03×10^{-9}
 - E. 2.03×10^9
3. The dissolution of calcium nitrate in water is an exothermic process. If the temperature is decreased from 75°C to 60°C , the solubility of calcium nitrate in water should
- A. increase
 - B. decrease
 - C. not change
 - D. change, but cannot predict how without more information
4. When SO_4^{2-} is converted to S^{2-} , _____ electrons are _____ by each sulfur atom.
- A. 0, lost or gained
 - B. 2, gained
 - C. 6, lost
 - D. 6, gained
 - E. 8, gained
5. Molarity is defined as :
- A. Moles of solute per kilogram of solution
 - B. Moles of solute per litre of solvent
 - C. Moles of solute per kilogram of solvent
 - D. Moles of solute per mole of solution
 - E. None of the above

6. For an aqueous solution at 25°C, if $[H_3O^+] = 0.050 \text{ mol L}^{-1}$, then $[OH^-] =$

- A. $2.0 \times 10^{-6} \text{ mol L}^{-1}$
- B. $5.0 \times 10^{-2} \text{ mol L}^{-1}$
- C. $2.0 \times 10^{-12} \text{ mol L}^{-1}$
- D. $1.0 \times 10^{-7} \text{ mol L}^{-1}$
- E. none of these

7. The following standard reduction potentials are valid for aqueous solutions at 25°C.

Reduction Half-Reaction	Standard Reduction Potentials E° (V)
$Hg^{2+} + 2e^- \rightarrow Hg$	0.851
$Ag^+ + e^- \rightarrow Ag$	0.800
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.770
$Cu^{2+} + 2e^- \rightarrow Cu$	0.340
$Sn^{2+} + 2e^- \rightarrow Sn$	-0.136
$Ni^{2+} + 2e^- \rightarrow Ni$	-0.230
$Fe^{2+} + 2e^- \rightarrow Fe$	-0.409
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.763
$Al^{3+} + 3e^- \rightarrow Al$	-1.706

From the E° values tabulated above, an element or ion which will oxidize tin but will not oxidize silver is

- A. Al
- B. Zn^{2+}
- C. Fe^{2+}
- D. Hg
- E. Cu^{2+}

8. Which of the following aqueous solutions has the lowest freezing point ?

- A. pure water
- B. $0.1 \text{ mol kg}^{-1} \text{ KBr}$
- C. $0.1 \text{ mol kg}^{-1} \text{ CaCl}_2$
- D. $0.1 \text{ mol kg}^{-1} \text{ sucrose}$
- E. $0.1 \text{ mol kg}^{-1} \text{ KCl}$

9. As an aqueous solution of a non-volatile solute becomes more concentrated, the difference in temperature between its melting and boiling points

- A. decreases
- B. increases
- C. remains constant
- D. may increase or decrease, depending on the solute
- E. increases if the solute forms two or more ions, otherwise decreases

10. Silver cyanide is soluble in water to the extent of $1.48 \times 10^{-4} \text{ mol L}^{-1}$ at 25°C . The value of K_{sp} for silver cyanide at 25°C is therefore:
- A. 6.5×10^{-13} (1.1)
 B. 2.2×10^{-13}
 C. 4.4×10^{-13}
 D. 3.2×10^{-13}
 E. none of these
11. As the equilibrium state of a chemical reaction is approached,
- A. The rate of the backward reaction approaches zero
 B. The rate of the forward reaction approaches zero
 C. The rates of the forward and backward reactions approach the same value
 D. Both A and B are correct
12. A catalyst
- A. may accelerate a reaction
 B. affects a reaction without being consumed in the process
 C. may be in same phase with the reactants or in a different phase
 D. all of these
 E. none of these
13. Consider the reaction,



If the equation were rewritten as $\text{NOCl(g)} \rightleftharpoons \text{NO(g)} + 1/2 \text{Cl}_2\text{(g)}$, the equilibrium constant for the new reaction would have the value:

- A. $2A$
 B. $A/2$
 C. \sqrt{A}
 D. A^2

$$\frac{2.10}{2} = 1.05$$

$$1.05^2 = 1.10$$

14. One reason that real gases deviate from ideality is because of the
- A. existence of attractive (or repulsive) forces between molecules
 B. finite size of the gas container
 C. small non-zero mass of the container
 D. small non-zero mass of each molecule

15. The reaction, $2A + B \rightarrow C$, is studied by monitoring the concentration of A. Over the first 3.2 minutes of observation, [A] decreases from $6.68 \times 10^{-2} \text{ mol L}^{-1}$ to $6.23 \times 10^{-2} \text{ mol L}^{-1}$. Thus the average rate of this reaction over this time period is
- $-4.5 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$
 - $1.41 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$
 - $4.69 \times 10^{-4} \text{ mol L}^{-1} \text{ s}^{-1}$
 - $2.34 \times 10^{-4} \text{ mol L}^{-1} \text{ s}^{-1}$
 - $1.17 \times 10^{-5} \text{ mol L}^{-1} \text{ s}^{-1}$
16. Reaction rates can change with
- temperature
 - the addition of a catalyst
 - reactant concentrations
 - all of A, B, C
17. A solution contains 0.2 moles of A, 0.4 moles of B and 0.4 moles of C. The mole fraction of B in this solution is approximately :
- 0.20
 - 0.22
 - 0.40
 - 0.67
 - 40%
18. For the reaction:
- $$2 \text{NOCl(g)} \rightarrow 2 \text{NO(g)} + \text{Cl}_2\text{(g)}$$
- the kinetics will be:
- Second order in NOCl
 - First order in Cl_2
 - Second order in NO
 - All of the above
 - Cannot predict
19. Which of the following has the largest mass?
- 1 mole of nitrogen molecules
 - 1 mole of ammonia molecules
 - 0.1 mole of lead atoms
 - 1 mole of fluorine atoms
 - 1 mole of methane molecules

20. How many of these are strong acids:

HCl(aq) , HF(aq) , HOCl(aq) , $\text{HClO}_4(\text{aq})$?

- A. 1
- B. 2
- C. 3
- D. 4

21. What mass of KIO_3 is needed to prepare 500.0 mL of a $0.0100 \text{ mol L}^{-1}$ solution of KIO_3 ?

- A. 2.14 g
- B. 1.07 kg
- C. $2.34 \times 10^{-3} \text{ g}$
- D. 1.07 g
- E. 4.28 g

22. What is the name of the ion whose structure is IO_4^- ?

- A. iodite
- B. periodite
- C. hypoiodite
- D. iodate
- E. periodate

23. Which of the following could be an empirical formula?

- A. C_6H_6
- B. N_2O_3
- C. $\text{C}_6\text{H}_{12}\text{O}_6$
- D. all of A, B, C
- E. none of A, B, C

24. Consider the precipitation reaction



If 0.30 moles of $\text{Na}_3\text{PO}_4(\text{aq})$ is mixed with 0.40 moles of $\text{CaCl}_2(\text{aq})$, the maximum number of moles of $\text{Ca}_3(\text{PO}_4)_2(\text{s})$ which can be obtained is:

- A. 0.40
- B. 0.30
- C. 0.20
- D. 0.15
- E. 0.13

25. Avogadro's number is defined as:

- A. the number of carbon atoms in 12 g of ^{12}C
- B. the number of carbon atoms in 1 g of ^{12}C
- C. the number of hydrogen atoms in 1 g of ^1H
- D. the number of gas molecules in 22.4 L of helium gas
- E. none of these.

II. Multiple Choice (5 marks each)

26. The mass percentage of oxygen in sodium perchlorate is:

- A. 13.1 %
- B. 52.3 %;
- C. 48.7 %;
- D. 58.5 %;
- E. 61.7 %;

27. From E° values tabulated in question 7, the standard potential for the electrochemical cell, $\text{Cu} | \text{Cu}^{2+} | \text{Fe}^{3+}, \text{Fe}^{2+} | \text{Pt}$ is

- A. 1.110 V
- B. 0.430 V
- C. 0.340 V
- D. 0.770 V
- E. none of these

28. How long will it take to plate 5.43 g of nickel onto an electrode from a solution of NiCl_2 at a current of 12.34 amperes?

- A. 1447 s
- B. 17850 s
- C. 723 s
- D. 0.0150 s
- E. none of these

29. A 5.42 L flask was evacuated to 2.37×10^{-10} mmHg at 75°C . How many molecules of an ideal gas would be present in the flask under these conditions?

- A. 2.71×10^{13} molecules
- B. 2.22×10^{10} molecules
- C. 3.56×10^{10} molecules
- D. 2.43×10^{14} molecules
- E. 1.34×10^{24} molecules

30. The constants in the van der Waals equation

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

are given for NH_3 and CO_2 as

	$a \text{ (L}^2 \text{ atm mol}^{-2}\text{)}$	$b \text{ (L mol}^{-1}\text{)}$
NH_3	4.170	0.03707
CO_2	3.592	0.04267

Based on these values, which statement is the most likely to be true for the intermolecular forces and molecular size?

- A. weaker forces, larger size for NH_3 than CO_2
- B. stronger forces, larger size for NH_3 than CO_2
- C. stronger forces, smaller size for NH_3 than CO_2
- D. weaker forces, smaller size for NH_3 than CO_2

31. Consider the equilibrium,



At 250°C the equilibrium partial pressures are $P_{\text{PCl}_3} = 0.400 \text{ atm}$, $P_{\text{Cl}_2} = 0.500 \text{ atm}$, and $P_{\text{PCl}_5} = 0.0930 \text{ atm}$. Therefore the equilibrium constant K for the reaction at this temperature is

- A. 2.15
- B. 0.465
- C. 8.60
- D. 0.116
- E. none of these

Handwritten notes:

$$K_p = K_c \left(\frac{1}{RT} \right)^{\Delta n}$$

III. Other Questions

32. (20 marks)

- a) For each substance listed below, indicate with a check mark whether it behaves as a Bronsted acid or base in dilute aqueous solutions, and give its conjugate partner.

	Acid	Base	Conjugate
(i) hydrocyanic acid	_____	_____	_____
(ii) fluoride ion	_____	_____	_____
(iii) ammonia	_____	_____	_____
(iv) acetate ion	_____	_____	_____
(v) hydroxyl ion	_____	_____	_____

- b) Predict the products of the following reaction and write a balanced net ionic equation for this reaction.



- c) Balance the following oxidation-reduction (redox) reaction, occurring in basic solution:



d) Draw the best Lewis structure for the OCN^- ion. (C is the central atom.)

e) A mixture of 34.0 g of ammonia and 50.0 g of oxygen reacts according to the equation



(i) What is the limiting reagent?

(ii) How many grams of water can form?

33. (5 marks)

An adult takes about 15 breaths per minute, with each breath having a volume of 500 mL. If the air that is inhaled is "dry", but the exhaled air at 1 atm pressure is saturated with water vapor at 37°C (body temperature), what mass of water is lost from the body during a 3 hour exam? The vapor pressure of water at 37°C is 47.1 Torr.

34. (5 marks)

Calculate ΔH° for the reaction: $\text{CO}_2(\text{g}) + 2 \text{NH}_3(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{NH}_2)_2(\text{s})$

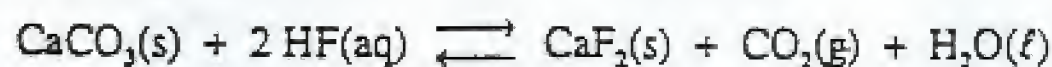
Substance	Standard Enthalpy of formation [kJ/mol]
$\text{CO}(\text{g})$	-110.53
$\text{CO}_2(\text{g})$	-393.51
$\text{CO}(\text{NH}_2)_2(\text{s})$	-632
$\text{H}_2\text{O}(\text{l})$	-285.83
$\text{H}_2\text{O}(\text{g})$	-241.82
NH_3	-46.11
$\text{NO}_2^-(\text{aq})$	-101.4
$\text{NH}_4^+(\text{aq})$	-132.51
$\text{N}_2(\text{g})$	0

35. (10 marks)

Intravenous solutions are often 5% (w/v) aqueous solutions of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$). What is the osmotic pressure of such a solution at 37°C ? Assume density of the solution is equal to 1.0 g/cm^3 .

36. (10 marks)

- a) Write the equilibrium constant expression for the following exothermic reaction, occurring in dilute aqueous solution:



- b) Specify how the quantity of CaF_2 at equilibrium will change (increase, decrease or no change) if:

i) More $\text{CaCO}_3(\text{s})$ is added to the system

ii) Some $\text{HF}(\text{aq})$ is removed

iii) The temperature is increased

iv) The volume is decreased

- c) Calculate the concentration of OH^- ions in an aqueous solution which has $\text{pH} = 5.75$.

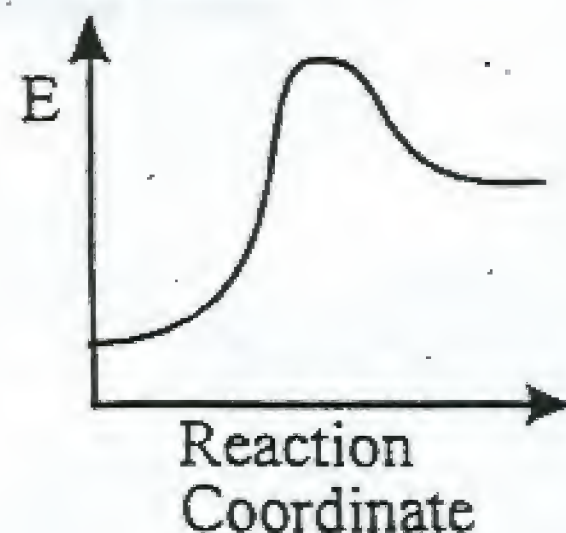
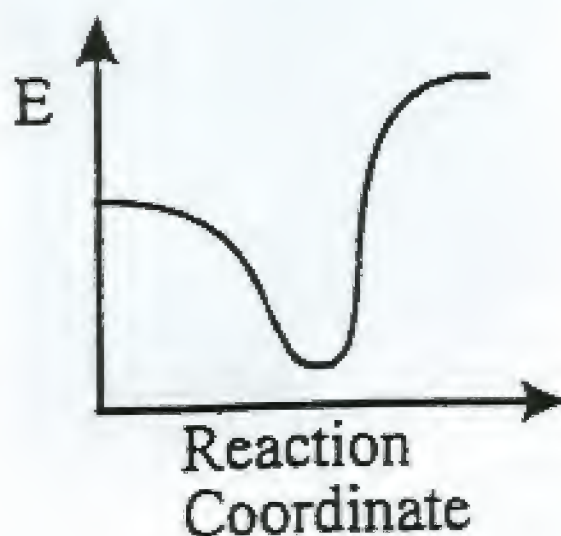
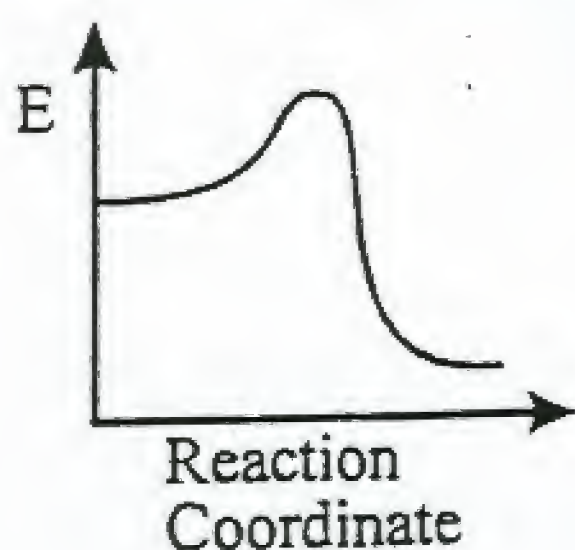
- d) What is the equilibrium concentration of H_3O^+ in a $2.0 \times 10^{-3} \text{ mol L}^{-1}$ solution of hypochlorous acid ($K_a = 3.1 \times 10^{-8}$)?

37. (10 marks)

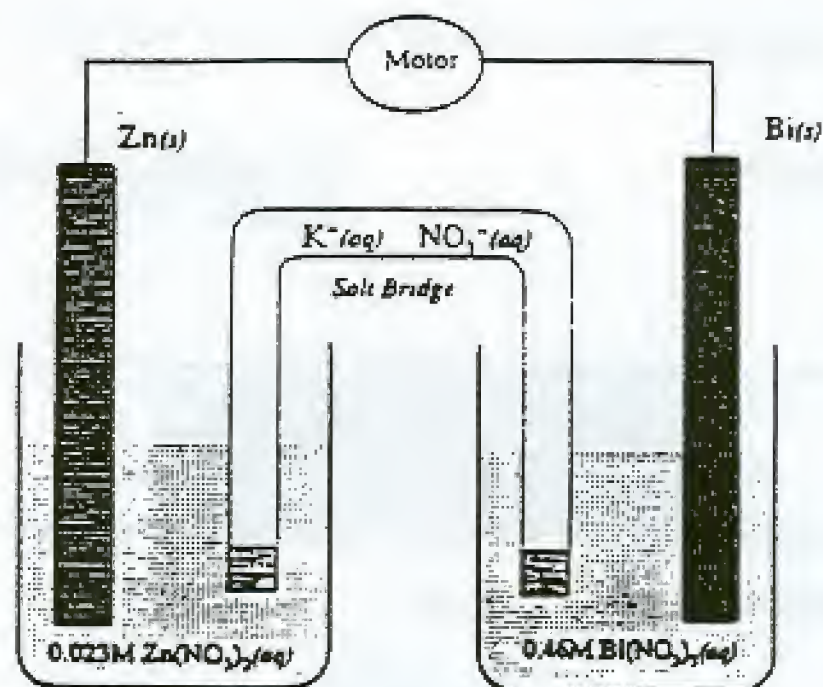
At temperature 25 °C the exothermic reaction $\text{NH}_4^+(\text{aq}) + \text{NO}_2^-(\text{aq}) \rightarrow \text{N}_2(\text{aq}) + 2 \text{H}_2\text{O}(\ell)$ produces the following data:

Initial Concentrations [mol L ⁻¹]		Initial Rate of Reaction [mol L ⁻¹ s ⁻¹]
$\text{NH}_4^+(\text{aq})$	NO_2^-	
0.20	0.061	3.24×10^{-6}
0.20	0.010	5.3×10^{-7}
0.10	0.061	1.62×10^{-6}

- a) Determine the rate law for the reaction.
- b) Determine the value of the rate constant at 25 °C, with proper units.
- c) One of the diagrams below correctly represents the reaction profile for this reaction. On the correct one, indicate the distances corresponding to the activation energy, E_a , for the forward reaction, and the enthalpy change for the reaction. Mark the location of the activated complex on the diagram.



38. (15 marks)



A miniature electric motor was connected to the electrochemical cell shown above. After 2.5 hours operation with the motor running the mass of the Zn electrode decreased by 1.23 g.

- a) Write the half-reactions for each electrode, and write the overall reaction taking place in the cell:

Anodic reaction: _____

Cathodic reaction: _____

Overall reaction: _____

- b) On the diagram above, label clearly:

i) the anode and the cathode;

ii) the polarity (+ or -) of the electrodes;

iii) the direction in which electrons move in the external circuit;

iv) the directions in which ions move in the salt bridge.

- c) Calculate the average value of the electrical current passing through the motor during the 2.5 hours of operation.

- d) Calculate the cell potential using the Nernst equation (standard potentials are given below).

Half-reactions



E° (V) vs. SHE¹⁾

0.36

-0.76

¹⁾ SHE is the standard hydrogen electrode

39. (5 marks)

Name the strongest attractive force that contributes to the interactions between molecules or ions in the following substances, and predict which substance has the highest normal boiling point.

Substance	Predominant intermolecular force 1)	Highest b.p. 2)
N ₂		
HF		
LiF		
CO		

Notes: 1) Provide an answer for each substance.

2) Check the cell corresponding to one substance only.

THE END

(4) (50)